CONCRETE PAVEMENT GUIDE

PART 3: PRESERVATION STRATEGIES

CHAPTER 310 – SPALL REPAIR

This chapter provides an overview of spall repair, also known as partial depth repair. A description of the effectiveness and limitations of spall repair, as well as material and design considerations, are included. Some limited information about spall repair construction is also included. Refer to the Construction Manual for more details about construction procedures.

310.1 PURPOSE AND DESCRIPTION

Spalling is the loss of concrete, typically around joints or cracks. Spall repair is a corrective maintenance treatment that replaces deteriorated concrete with polyester or fast-setting concrete. Spall repair extends pavement service life and inhibits deterioration by:

- Restoring the structural integrity of the pavement
- Improving ride quality
- Restoring the joint seal reservoir

Depending on the existing pavement condition, spall repairs can be used as the primary pavement strategy or in combination with other corrective, preventive, or rehabilitation strategies. Common combinations include repair of additional spalled joints and cracks on individual slab replacement projects, as a pre-overlay repair to prepare a distressed pavement surface, or prior to grinding or joint sealing.

310.1.1 Spall Repair Applications and Limitations

Spall repair restores localized surface deterioration in joints, cracks, or miscellaneous areas within the upper 1/3 of the concrete slab depth. Spall repair is commonly used to repair isolated spalling between 6” and 6’ long caused by:

- Incompressible material in joints or cracks
- Localized areas of weak material from poor consolidation, curing, or finishing practices
- Joint inserts

More severe spalling distress is typically treated using partial or complete individual slab replacement with rapid strength concrete (see Chapter 320).

a) Transverse crack

b) Slab corner

Figure 310–1: Spall repair candidates

Spall repair should be used as the principal strategy on a project if it is the primary distress and more than 25% of the slabs in a pavement segment length have medium severity spalling between 1-2 ft^2. Extensive severe spalling of greater than 2 ft^2 per slab over more than 15% of a pavement segment length may require a rehabilitation or reconstruction project strategy.

Table 310-1 illustrates the levels of spalling severity and extent where various strategies should be applied:

Table 310–1: Spall Repair Strategy Selection

Spalling Severity (per slab)	Area (ft^2)	Management Segment Extent (%)	Primary Pavement Strategy Recommendation	Reference
Low	< 1	100	None	Automated Pavement Condition Survey (APCS) Manual
Medium	**1–2**	1–25	None	APCS Manual
		> 25	**Spall repair**	**Chapter 310**
High	> 2	1–15	▪ Individual Slab Replacement (RSC)***** ▪ HMAOL*****	▪ Chapter 320 ▪ Chapter 370
		> 15	▪ Lane replacement ▪ CSOL***** ▪ Concrete overlay*	▪ Chapter 400 ▪ Chapter 410 ▪ Chapter 420

*****Some spall repair work may be appropriate on a project in combination with the primary strategy. See Chapter 100 and the applicable Concrete Pavement Guide chapter for more information.

Spalls caused by material problems such as alkali-silica reactivity (ASR) or vertical movement from shrinkage, fatigue, or failing dowel bars usually indicate deterioration beyond the upper 1/3 of the pavement thickness. If localized, these distress mechanisms should be treated using individual slab replacement instead of spall repair. More extensive distress should be treated by one of the rehabilitation or reconstruction strategies in Table 310-1.

310.2 MATERIALS AND SPECIFICATIONS

Spall repair material specifications are in 2010 Standard Specification Section 41-1. Section 41-4 requires polyester concrete for spall repair, but SSP 41-4 allows use of fast-setting concrete for pre-overlay repairs or with district maintenance engineer approval, typically for short-term repairs with an anticipated service life ≤ 5 years.

310.2.1 Polyester Concrete

Polyester concrete consists of an unsaturated isophthalic polyester-styrene copolymer resin binder and dry aggregate. A silane coupler is used to increase the resin bonding strength, and a high-molecular-weight methacrylate (HMWM) bonding agent is applied to penetrate microcracks in the substrate surface and increase shear strength at the bond interface.

Despite higher cost, polyester concrete is preferred when compared to fast-setting concrete materials for most applications due to generally superior performance over a wider range of conditions. Polyester concrete cures rapidly, developing high compressive strength and good concrete adhesion for placement over a wide surface temperature range between 40 and 130 °F. The polyester resin gel time can be adjusted for conditions anticipated in the field by adjusting the initiator percentage according to manufacturer recommendations.

Minimum polyester concrete material property requirements for viscosity, specific gravity, elongation, tensile strength, styrene content, silane coupler, saturated surface dry bond strength, and static volatile emissions are in 2010 Standard Specification Section 41-1.02C.

310.2.2 Fast-Setting Concrete

Fast-setting concrete can be magnesium phosphate, modified high-alumina, or portland cement based concrete. The type is selected by the contractor considering available curing time, climatic conditions, material costs, equipment requirements, working time for mixing and placing, and the size and depth of the repairs.

- Magnesium phosphate cement concrete mixtures are characterized by a high early strength, low permeability, and good bonding to clean dry surfaces. Use of epoxy bonding agent may be recommended by some manufacturers, and set time can be retarded to prevent reduced bonding strength. Workability is limited as significant strength reduction can occur from very small amounts of excess water.

- Modified high-alumina cement concrete mixtures produce rapid strength gain with good bonding properties to dry or damp surfaces and very low shrinkage. High-alumina cement is modified by adding calcium sulfate to reduce strength loss under high temperatures and moist conditions. Set retarders and accelerators are available from some manufacturers to adjust for variable field conditions.

- Portland cement type I, II, or III is typically considered preferable for spall repairs. Since tight lane closure restrictions often limit construction and curing time, non-chloride accelerating admixtures that comply with 2010 Standard Specification Section 90-1.02E and ASTM C494/C494M can be used to achieve high early strength and reduce the time to open for traffic. Calcium chloride ($CaCl_2$) accelerators are not allowed since they produce excessive shrinkage and dowel bar corrosion. Insufficient curing time, incompatible mixtures, or poor mix proportioning can cause premature deterioration and failure of the repair.

Minimum fast-setting concrete property requirements for compressive strength, flexural strength, bond strength, water absorption, abrasion resistance, drying shrinkage, water soluble sulfates and chlorides, and thermal stability are in 2010 Standard Specification Section 41-1.02B. Notably, a relatively high opening compressive strength of 3000 psi after 3 hours is required. In general, high early strength requirements result in higher cement content and more complex mixtures with greater failure potential. If the available traffic window allows a slower setting mixture, contact the Office of Concrete

Pavement in the Headquarters Division of Maintenance or submit a non-standard special provision (nSSP) request to: nssp.submittals@dot.ca.gov.

Table 310–2: Spall Repair Material Properties

Spall Repair Material		Approximate Working Time* (minutes)	Approximate Time To Traffic* (hours)	Repair Surface Temperature	Repair Surface Condition
Polyester concrete		20	2	40 - 130 °F	HMWM bonding agent
Fast-setting concrete	Magnesium phosphate cement	15	1	40 - 90 °F	dry
	Modified high-alumina cement	15	1	> 40 °F	bonding agent or damp
	Portland cement (with accelerator)	120	4	> 40 °F	bonding agent or damp

*At 72 °F. Refer to manufacturer's recommendations for more information.

310.2.3 Bonding Agents

A HMWM bonding agent is required with polyester concrete spall repairs to enhance the bond between the existing concrete and the repair material.

For fast-setting concrete, a bonding agent must be used if recommended by the concrete manufacturer. The bonding agent must comply with manufacturer recommendations, but epoxies have been widely used on these types of repairs.

If the fast-setting concrete manufacturer does not recommend a bonding agent, portland cement and modified high-alumina cement concrete can be placed on a damp surface that is not saturated. Magnesium phosphate cement concrete must be placed on a dry surface.

310.2.4 Other Repair Material Types

There are cost effective nonstandard repair material alternatives available such as polyurethane and pozzolanic materials that have performed well in various field maintenance applications. Others, such as gypsum, methacrylate, and epoxy have been evaluated and are not used by Caltrans due to issues with performance or cost effectiveness.

Additional materials, including some proprietary products that are not currently standardized for spall repair on contract projects, could be included in an authorized material list for concrete repair materials if one is developed for future specification updates. If there is interest using a specific nonstandard spall repair material on a project in the interim, contact the Office of Concrete Pavement in the Headquarters Division of Maintenance or submit an nSSP request to: nssp.submittals@dot.ca.gov.

310.3 DESIGN

Spall repair performance can be highly improved through proper design. This section provides important design considerations for spall repairs, such as concurrent work, repair locations and boundaries, and cost estimating.

310.3.1 Order of Work

The sequence of work is very important for spall repairs done as part of a comprehensive pavement project using various strategy combinations. The project special provisions should specify the following order of work requirements for applicable operations:

1. Slab subsealing or jacking should be done before spall repair so any accidental spalling that occurs can be readily repaired.
2. Spall repairs should be done before or concurrently with isolated slab replacement in case adjustments to locations or boundaries are necessary as construction proceeds.
3. Diamond grinding should follow spall repair, isolated slab replacement, and dowel bar retrofit.
4. Joint sealing or joint seal replacement should be completed as needed following other treatment strategies.

310.3.2 Repair Locations and Boundaries

Visual surveys are needed to identify spall locations and estimate spall repair area quantities during preliminary and final project design, and to mark repair boundaries during construction.

The pavement management system contains a visual record of every mainline concrete slab in the state, accessible online through the iVision software program at https://ivision.fugro.com/CaliforniaSH/#/Login. Visual and distress data are scheduled for collection biannually, so the available information can provide approximate pavement conditions but may not reflect the most current conditions, which should be verified with a field review to identify spall repair locations and estimate dimensions for quantities. Although lane closures may be difficult to obtain on high traffic volume routes, an effort should be made to estimate the depth of severely spalled areas. It may be possible to effectively survey the traveled way from median and outside shoulder areas during non-peak daytime hours. If existing spalls are deeper than 1/3 the slab thickness, individual slab replacement with rapid strength concrete should be used as the repair strategy.

A follow-up field evaluation should be performed by experienced construction personnel to define soundness limits as close as possible to the scheduled repair work so any additional spalling that developed since the design estimate is included. Engineering judgment, coring, and sounding techniques are used to identify the extent of the deterioration beneath the surface and determine accurate repair boundaries.

- The resident engineer will typically determine rectangular unsound concrete limits by sounding, which is listening for a dull, hollow sound after striking the concrete surface with a hammer, steel rod, or dragging chain.
- At least 2” beyond the unsound limits, the contractor will mark the saw cut lines for measurement and payment by the square yard.
- The actual spall repair area will also be marked by the contractor. The boundaries must extend at least 2” beyond the saw cut line, where concrete will be removed and tapered to form a rough surface sloped at 0.6:1 or flatter (between 30° and 60°) to finished grade. The additional tapered area beyond the saw cut is not paid for and should not be included in the spall repair area quantity estimate.
- Regardless of soundness limits, repair boundaries for spall repairs should extend at least 5” beyond the edge of the existing spalled surface.
- Spall repair areas closer than 2’ apart should be combined.
- If the spall repair area is less than 6” from a joint, the repair boundaries should be extended to the joint.

For more information about spall repair boundaries, refer to Figure 310-2 and 2010 Revised Standard Plan RSP P6.

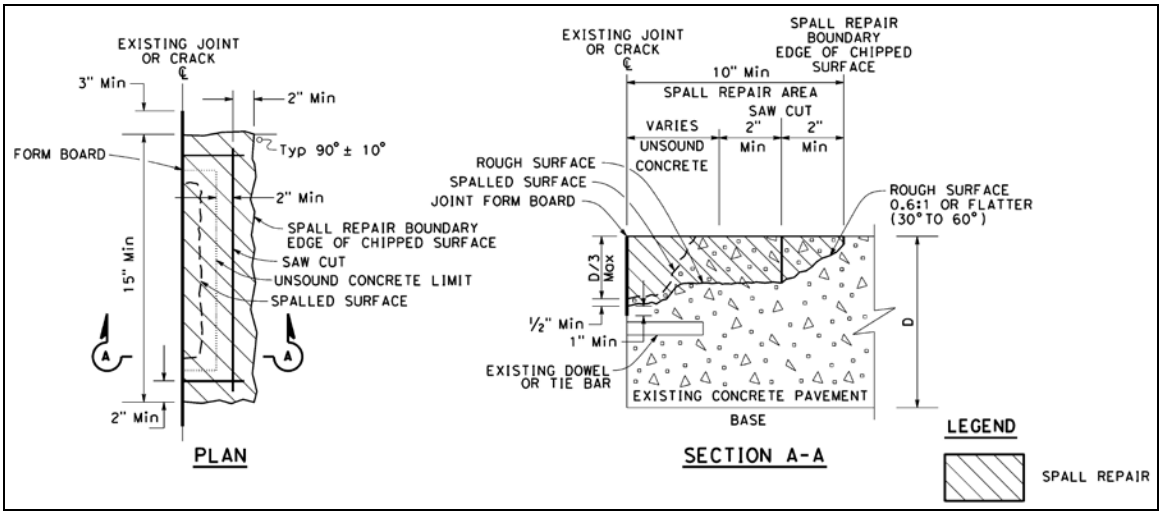

Figure 310–2: Typical spall repair at a joint or crack

Spall repair locations should be shown on the quantity plan sheets by post mile, station, or slab number. Spall repairs are measured by saw cut area, but the average length and width can be listed in the quantity table for additional information if designated as separate, nonpaid items. Given inherent variability, the plans should include a note that the Engineer will determine the exact spall repair locations and dimensions. For individual slabs with multiple spall repair locations, a typical construction detail or coded description and details can be used.

310.3.3 Cost Estimating

It is critical to make a reasonable estimate in the Project Report (PR) or Project Scope Summary Report (PSSR) when programming project funding for spall repair. Estimates should be based on identified locations and boundaries but reasonably conservative to avoid underestimation, account for invisible deterioration below the pavement surface, and anticipate additional deterioration prior to construction.

For the engineer's estimate at PS&E, any previous quantity estimates should be updated to reflect existing distress levels. Quantities should be based on the most recent pavement condition data from the pavement management system and verified with a field review as close to PS&E as possible (see Section 310.3.2). The updated estimate should also account for future deterioration likely to occur prior to scheduled project construction, which can be predicted using deterioration rates established from historical pavement condition data or percentage rates based on engineering judgment.

Table 310-3 provides the minimum dimensions for estimating spall repair area quantities, not the actual constructed spall repair area dimensions, which vary with concrete soundness.

Table 310–3: Estimating Spall Repair Quantities

Location of Spalling	Estimated Minimum Spall Repair Dimensions* (inches)		
	Depth	Length (Transverse)	Width (Longitudinal)
transverse joint or crack	2”	11” or spall length + 3”	8” or spall width + 3”
longitudinal joint, crack, or edge of concrete pavement	2”	8” or spall length + 3”	11” or spall width + 3”
miscellaneous repair area	2”	6” or spall length + 3”	6” or spall width + 3”

*Dimensions are relative to the traffic direction. Use the larger dimension to estimate repair area.

Accurate quantity estimates should be within 75 to 125% of the actual amount repaired during construction. The spall repair area quantity will fluctuate during construction because field conditions change and the resident engineer determines the actual limits of unsound concrete, which the contractor uses to determine the saw cut lines and repair boundaries. Accordingly, the unit price bid for spall repair is not adjusted for changes to the construction quantity.

Initial costs can be estimated using historical contract cost data for all contracted bid items and other information available on the Division of Design cost estimating website at http://www.dot.ca.gov/hq/oppd/costest/costest.htm. Typical bid items for spall repair work are shown in Table 310-4. As of 2013, the current standard bid items for spall repair are item 410120 Spall Repair (Polyester Concrete) and item 410121 Spall Repair (Fast-setting Concrete), but unit cost data may be limited. Previously item codes 413111, 413112, or 413113 were used for spalled joint repair. If historical spall repair cost data for a material is limited or not reasonable for the project conditions, adjust the unit cost estimate for differences in available data.

When estimating the cost to repair spalled joints, an estimate for replacing the entire joint seal length along the slab is also required. Replacing joint seals will reduce future spalls by preventing intrusion of incompressible materials and surface water. Use the bid item for the appropriate seal material. Both longitudinal and transverse repair joints must be resealed according to 2010 Standard Specification Section 41-5 using asphalt rubber, silicone, or preformed compression seal material. On projects bid prior to 2014, the joint seal replacement cost may have been included in the spall repair bid item or paid separately but limited to damage along the spall repair area. For more detailed information on joint sealing, refer to Chapter 360.

Table 310–4: Typical Spall Repair Work Bid Items

2010 and 2015 Standards			Prior Standards (for estimating unit costs only)	
Item Code	Description	Unit	Item Code	Description
410120	Spall Repair (Polyester Concrete)	SQYD	413113	Repair Spalled Joints (Polyester Grout)
410121	Spall Repair (Fast-setting Concrete)	SQYD	413112	Repair Spalled Joints (Fast-setting Grout)
---	---	---	413111	Repair Spalled Joints
414222 - 414224	Replace Joint Seal (Preformed Compression) - *3 size ranges*	LF	413114	Replace Joint Seal (Existing Concrete Pavement)
414221	Replace Joint Seal (Silicone)	LF	414119	Replace Concrete Pavement Joint (Silicone)
414220	Replace Joint Seal (Asphalt Rubber)	LF	414120	Replace Concrete Pavement Joint (Asphalt Rubber)

Current contract standards including plans, specifications, and bid items are on the Division of Engineering Services Office Engineer website at:
http://www.dot.ca.gov/hq/esc/oe/construction_standards.html.

310.4 CONSTRUCTION PROCESS

Some key information about spall repair construction is summarized in this section. Refer to the Construction Manual for more details about spall repair construction procedures.

310.4.1 Spall Repair Construction Sequence

The spall repair construction sequence is:

1. Engineer determines rectangular limits of unsound concrete (see Section 310.3.2). For projects with multiple, smaller spalled areas where sounding may not be efficient or safe for field conditions, the minimum dimensions in Table 310-3 can be used to establish the repair boundaries. The saw cut area used to measure pay quantities must be inset at least 2" in all directions from the outer repair boundary (see RSP P6).
2. Contractor marks the saw cut lines and spall repair area (see Section 310.3.2)
3. Saw cut and remove concrete pavement. Chip at least 2" beyond the saw cut to produce a rough surface angled from 30° to 60° (see Section 310.4.2). Leave a slight vertical face at the surface where the repair material conforms to the existing pavement to allow for aggregate thickness.
4. Clean the exposed concrete surfaces by sand or water blasting and blowing with compressed air (see Section 310.4.3)
5. Prepare the joint by placing a form board along the existing joint or crack alignment (see Section 310.4.4)
6. Place polyester concrete using a bonding agent or fast-setting concrete according to the manufacturer's instructions
7. Finish and cure the concrete repair material according to the manufacturer's instructions
8. Open to traffic (see Section 310.4.5)

310.4.2 Concrete Sawing and Removal

2010 Standard Specification Section 41-4 requires saw cutting with a diamond bladed saw at least 2" beyond the unsound concrete limit. The saw cut must be at least 1.5" deep for repairs using polyester concrete and 2" deep for fast-setting concrete. The spall repair depth should not extend more than 1/3 of the concrete slab thickness or 3.5" maximum, but must be at least a ½" below the existing spalled surface and deep enough to remove any deteriorated concrete.

No specific method is required for concrete removal, but typically 15 lb jackhammers are used to chip out the damaged concrete from the center of the repair area out towards the saw cut to the full cut depth:

- Concrete must be removed at least 2" beyond the saw cut toward the boundary edge and tapered at a rate of 0.6:1 or flatter (about 30° to 60°) to finished grade. The tapered edge results in a rough substrate surface that increases the surface area and bonding strength at the interface.
- At the repair boundary edge, a slight vertical face should be chipped out according to the repair material manufacturer recommendations to avoid a thin, feathered conform that could cause future spalling.

310.4.3 Cleaning

The repair surface must be thoroughly clean before the application of repair material to enhance bonding between the repair material and the existing concrete. Abrasive sandblasting or high-pressure water blasting, followed by compressed air blasting, are used to clean the exposed concrete substrate.

310.4.4 Joint and Crack Preparation

Adequate joint and crack preparation is essential to the performance of spall repairs. Repairs adjacent to joints and cracks require sufficient space to minimize the development of compression forces due to thermal expansion of the slabs. Also, a repair material that infiltrates the crack or joint can restrict slab movement and cause the development of compressive stresses at lower depths that will deteriorate the repair. This type of deterioration can also occur along longitudinal joints or at lane-shoulder joints.

Spall repair failures can be reduced by placing a compressible form board in the joint or crack between the repair material and the adjoining pavement. Once the repair material has cured, the form board must be removed before sealing the joint or crack.

310.4.5 Opening to Traffic

Regardless of the material used, spall repairs must cure for at least 2 hours from the time of final setting determined under ASTM C403/403M before opening to traffic. If the repair cannot be completed within the specified lane closure time, temporary pavement structure must be constructed according to the provisions in 2010 Standard Specification Section 41-1 and removed as a first order of work.

REFERENCES

Caltrans, 1991. *New Materials and Techniques for the Rehabilitation of Portland Cement Concrete,* Final Report 2nd Edition, Sacramento, CA, 1991.

National Concrete Pavement Technology Center, 2012. *Guide for Partial-Depth Repair of Concrete Pavement*, Iowa State University, Ames, IA, April 2012.

Carmichael III, R. F., A. H. Meyer, L. L. Caldwell, and B. F. McCullough, 1989. *Rapid Replacement of Portland Cement Concrete Pavement Segments*, NCHRP Research Results Digest Number 169, Transportation Research Board, Washington, DC, 1989.

FHWA, 2006. *Partial Depth Repairs*, Federal Highway Administration website: http://www.fhwa.dot.gov/pavement/concrete/full.cfm/

FHWA, 1999. *Materials and Procedures for Rapid Repair of Partial-Depth Spalls in Concrete Pavements. Manual of Practice*, Report No. FHWA-RD-99-152, Federal Highway Administration, Washington, DC, 1999.

FHWA, 2001. *PCC Pavement Evaluation and Rehabilitaion*, NHI Course 131062, Federal Highway Administration, Washington, DC, October 2001.

FHWA, 2004. *Pavement Preservation Design and Construction of Quality Preventive Maintenance Treatments*, NHI Course 131103, Federal Highway Administration, Washington, DC, November 2004.

Wilson, T. P., K. L. Smith, and A. R. Romine, 1999a. *LTPP Pavement Maintenance Materials: PCC Partial-Depth Spall Repair Experiment*, FHWA-RD-99-153, Federal Highway Administration, McLean, VA, 1999.

Wilson, T. P., K. L. Smith, and A. R. Romine, 1999b. *Materials and Procedures for Rapid Repair of Partial-Depth Spalls in Concrete Pavement, Manual of Practice*, FHWA-RD-99-152, Federal Highway Administration, McLean, VA, 1999.